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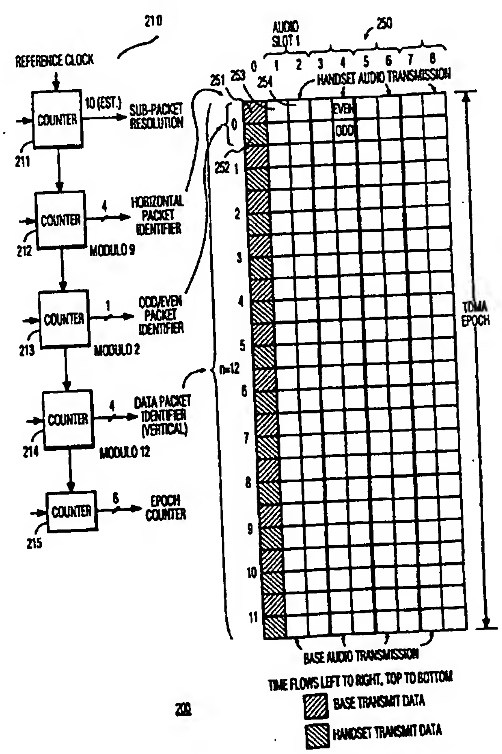
(54) Title: POWER SAVING PROTOCOL FOR TDMA MULTI-LINE WIRELESS TELEPHONE HANDSETS

(57) Abstract

A wireless telephone system comprises a base unit having a base transceiver, and one or more wireless handsets, each handset comprising a handset transceiver. Each handset establishing a time-division multiple access (TDMA) link over a shared RF channel with the base unit via the base transceiver in accordance with a TDMA epoch, which allocates exclusive data and audio packet time slots to each handset. Each handset powers on its transceiver during its respective data and audio packet time slots as necessary to synchronize with the base unit using synchronization data transmitted with a data packet, to detect incoming call data transmitted with a data packet, or to transmit and receive audio information over the TDMA link. The handset powers off its transceiver otherwise during the epoch to minimize handset power use.



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POWER SAVING PROTOCOL FOR TDMA MULTI-LINE WIRELESS TELEPHONE HANDSET

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to multi-line wireless telephone systems and, in particular, to techniques for saving power in battery-operated wireless handsets in wireless telephone systems.

Description of the Related Art

The use of telephones and telephone systems, including wireless telephone systems, is widespread. In wireless telephone systems, a cordless or wireless telephone handset unit communicates via either analog or digital radio signals with a base unit, which is typically connected via a standard telephone line to an external telephone network. In this manner, a user may employ the wireless handset to engage in a telephone call with another user through the base unit and the telephone network.

Multi-line wireless telephone systems are also in use in various situations, such as businesses with many telephone users. Such systems employ a handset that communicates with up to N handsets simultaneously, typically with digital communications schemes, such as a spread-spectrum, time division multiple access (TDMA). In a TDMA system, a single RF channel is used, and each handset transmits and receives data during a dedicated time slice or slot within an overall cycle or epoch. Efficient power use is important for a wireless system since the handsets are typically battery-powered.

SUMMARY

A wireless telephone system comprises a base unit having a base transceiver, and one or more wireless handsets, each handset comprising a handset transceiver. Each handset establishing a time-division multiple access (TDMA) link over a shared RF channel with the base unit via the base transceiver in accordance with a TDMA epoch, which allocates exclusive data and audio packet time slots to each handset. Each handset powers on its transceiver during its respective data and audio packet time slots as necessary to synchronize with the base unit using synchronization data transmitted with a data packet, to detect incoming call data transmitted with a data packet, or to transmit and receive audio information over the TDMA link. The handset powers off its transceiver otherwise during the epoch to minimize handset power use.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of TDMA multi-line wireless telephone system, in accordance with an embodiment of the present invention;

Fig. 2 is a schematic representation of the TDMA slot structure and handset counters used in the TDMA scheme of the system of Fig. 1, in accordance with an embodiment of the present invention; and

Fig. 3 is a state diagram of the power saving protocol implemented by each handset of the telephone system of Fig. 1, in accordance with an embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to Fig. 1, there is shown a block diagram of TDMA multi-line wireless telephone system 100, in accordance with an embodiment of the present invention. TDMA system 100 comprises a base unit 110, which has receiver and transmitter units 112 and 111, respectively, and is coupled to external telephone network 116 via telephone line(s) 115. System 100 also comprises N wireless handsets 120_1, 120_2, . . . 120_N. Each has a transmitter and receiver unit (transceiver), such as transmitter 121 and receiver 122 of handset 120_1. At any given time, some number (or none) of the handsets are operating or off-hook (i.e., in the process of conducting a telephone call). System 100 thus provides a wireless network between the base station 110 and each handset 120_i ($1 \leq i \leq N$). In one embodiment, system 100 comprises 4 handsets 120_1–120_4, all of which may be active simultaneously. In another embodiment, system 100 comprises a different number of handsets, e.g. N=12, of which up to 8 can be active or operational at a time.

As explained above, efficient power use is important for a wireless telephone system since the handsets are typically battery-powered. In one embodiment, therefore, the present invention comprises a TDMA system and protocol for connecting multiple transceivers to a base station over a single RF channel. In particular, system 100 employs a digital TDMA scheme, as described in further detail below, which allows power to be efficiently used since each operating handset is "off" (i.e., not transmitting or receiving data, and thus not using as much battery power) during most portions of the TDMA epoch, and is only "on" during its own time slices or slots, as

described in further detail below. In one embodiment, a handset powers off by switching off power to at least its CPU and transceiver (receiver and transmitter) units, while leaving powered on only a clock and associated timer or watchdog circuitry sufficient to wake up the CPU at a predetermined slot time.

However, use of a time-division multiplexing (TDM) technique such as TDMA, and switching each transceiver (handset) on only during its own time slots can give rise to various problems. For example, because handsets use an RF energy detector to sense when a signal is being transmitted from base station 110 to one of the handsets, communication intended for one handset may activate other handsets, causing unnecessary battery draining in those other handsets. In the present invention, therefore, the handsets are carefully synchronized so that each handset only "listens" for transmissions in its own time slots.

Without the present invention, there may be a tendency for the local time bases of the handsets to drift with time, which could result, after a period of time, in each handset listening to all transmissions to resynchronize to base unit 110. After such synchronization, the handset could be once again able to listen only in its time slot. However, since "listening" requires power, when synchronization is lost, there will be wasteful use of battery power. In addition, if synchronization is lost, the link integrity can be lost, due to signal collision, which occurs when multiple devices try to use a single RF channel at the same time.

Therefore, each handset 121_i employs the protocol of the present invention, as described in further detail below, to allow this switching on and off to occur, without loss of synchronization. The

synchronization protocol of the present invention allows each remote, independent handset to use local time bases to synchronize to the TDMA sequence from the base station, synchronizing on certain transmissions from the base, and then listening only in the appropriate time slot.

Referring now to Fig. 2, there is shown a schematic representation of the TDMA slot structure 250 and handset counters 210 used in the TDMA scheme 200 of the system of Fig. 1, in accordance with an embodiment of the present invention. System 100 employs a TDMA epoch having structure 250, which is illustrated assuming 12 total handsets 120_1-120_{12}, of which 8 can be active or operational at a time, e.g. handsets 120_1-120_8. TDMA epoch structure 250 comprises a number of rows and columns. Each row of TDMA structure 250 represents a 2ms field of digital data, and is either even or odd and grouped in a pair with an odd or even, respectively, row or field. TDMA epoch structure 250 is a 48ms epoch.

Each field of digital data comprises nine total packets: a data packet in the first column (either transmitted from the base or from a handset) and eight audio packet, grouped in 4 pairs of two. Each such pair of audio packets in a row includes one packet (time slot) of base audio transmission (to a given handset from base unit 110) and one packet of handset audio transmission (from the given handset to the base). Each data packet is a set of data transmitted either to a given handset from the base unit or vice-versa, during a discrete time slot during which time no other handsets receive or transmit data over the system's data channel. These data packets may contain various types of data, such as synchronization data or words with time stamp

information transmitted to a handset in sleep mode, caller ID information, incoming call information, and the like. Data packets transmitted from a handset to the base may contain information such as the telephone number being dialed by the handset. Each audio packet is a set of audio data transmitted either to a given handset from the base unit or vice-versa, during a given time slot in the overall epoch, again during which time no other handsets receive or transmit data over the system's single RF channel.

Thus, for example, row pair 0 comprises an even row and odd row. In the even row, the base transmits data in the first time slot (slot 251), to one of the 12 handsets, e.g. handset 120_1. There is one row pair in epoch 250 for each handset, so that each handset can receive and transmit data to base unit 110 once per epoch. After the first data slot 251, assuming handset 120_1 is operational (off hook), an audio packet is transmitted to handset 120_1 in audio packet slot 253, then an audio packet is transmitted by handset 120_1 to base unit 110 in audio packet slot 254, and so on for 3 of the other handsets until the end of the field or row. In the odd row for row pair 0, data slot 252 is used to receive data transmitted from handset 120_1 to base unit 110, and audio packets are transmitted for the remaining 8 active handsets. In row pairs 1-11, the same sequence occurs, except the data packets are to and from different handsets than for row pair 0.

In the present invention, a time base capable of resolving a fraction of a time slot over the period of several seconds is established in each handset which matches the TDMA slot timing in base unit 110. The TDMA epoch structure 250 is known by both each handset and the base, and once the time bases are synchronized, the

handset receiver will know when it should listen for transmissions from the base, and it will know when it should send data back to the base. Keeping the TDMA slots known to within microseconds over a one second interval requires that a very stable and accurate reference be provided to operate this time base.

To eliminate collisions in the protocol, all handsets are given a designated data time slot, and audio time slots are allocated dynamically, according to which handset needs them. This information is communicated over the data channel (the first column of TDMA structure 250). The TDMA slots are divided into data and audio slots in a two-dimensional arrangement, as illustrated in Fig. 2. The base transmits synchronization packets to handsets in their respective data slots until a call is initiated.

Each handset maintains a cascade of counters 210, to keep local timing of each handset from drifting and thus in synchronization with the TDMA sequence. This is done be applying a reference clock signal to first counter 211 (all counters are initialized at some previous point, which initialization may proceed in stages). The reference clock signal is provided by a local clock in the handset, which is periodically adjusted as necessary, to correct for drifting, in accordance with time stamp synchronization information transmitted by base unit 110 during data packet slots. Counter 211 keeps track of sub-packet resolution, and identifies which bit of the packet is being processed, out of, for example, 100 bits per audio packet. Counter 212 keeps track of the horizontal packet, or time slot (i.e., the column number of the current row or field of TDMA epoch structure 250). Counter 213 keeps track of whether the current row is odd or even, and counter 214 keeps track of whether or not the current packet is a data packet

or not, and which handset the data packet correlates with, and whether the data packet is to or from the base unit 110. Finally, counter 215 keeps track of which epoch the system 100 is in. This may be useful in requesting retransmission of corrupted data sent by base unit 110 during a certain epoch, for example..

The TDMA system of the present invention saves power by turning off most components of the handset, other than an internal clock and watchdog circuitry, for most of the TDMA epoch. The internal clock and protocol implemented by each handset ensures that synchronization is not lost, however, even though the handset is powered down. Thus, power is saved, but synchronization is not lost. Each handset may be in one of two states: in sleep mode, or operational mode.

In sleep mode, when the handset is on hook, only an internal clock and watchdog timer runs for most of the time, where the clock has previously been synchronized to the base unit clock and epoch. Thus, in sleep mode, the handset is configured so that it will wake up and "listen" for data during its assigned "receive data" slot, and turn off again thereafter if there is no incoming call. The wake up is caused by the watchdog timer counting down to a certain value, which switches on the CPU and other components necessary to listen for and/or transmit data. During this data slot, the handset receives synchronization data from base unit 110 and adjusts its internal clock, if necessary, to correct for any drifting. In the very next data slot, the handset may wake up again to acknowledge that it is alive and synchronized by transmitting a suitable "I'm alive" data message to base unit 110. Thus, in one embodiment, when in sleep mode, each handset is on for only two data packets of the entire TDMA epoch, a

duty cycle of approximately 0.93% (2 slots/(9x12x2 slots)). Powering up to allow the handset to listen to a data packet transmission from base unit 110 once every 48ms epoch is sufficient to allow a handset to stay synchronized (i.e., to keep the communication loops in lock), and also to allow any incoming calls to be detected quickly enough to alert the user of incoming calls (e.g., to allow caller ID information to be viewed and/or calls to be answered in real time).

In an alternative embodiment, the handset skips a number of epochs entirely, and, for example, wakes up during its data slots only once during every 3rd epoch, as this will also be sufficient for synchronization and real time incoming call monitoring. This reduces the duty cycle further. The "I'm alive" message from the handset (e.g., transmitted in data slot 252) need not be transmitted every epoch, or even every epoch when the handset wakes up and listens to data from base unit 110. Preferably, these parameters are user programmable. For example, a handset may be programmed to wake up every 3rd epoch and listen during its data slot, and to transmit back an "I'm alive" message every 6th epoch. In this case, the base unit, which does not have similar power constraints, will nevertheless transmit synchronization data every epoch but will know that the handset is adequately synchronized as long as an "I'm alive" data message is received every 6 epochs. Otherwise, base unit 110 can assume that lock has been lost and can then try to restore the link, e.g. by transmitting data/sync packets to the lost handset at three increasing power levels, during its respective data packet slot. Lock may be lost, for example, when the handset battery is changed, or when the handset stays out of range for a duration longer than handset TDMA timing can tolerate. This effectively increases the

dynamic range of the system. For example, with 30dB of power control and 70dB of automatic gain control (AGC), the system can acquire lock over a 100dB dynamic range.

If a handset detects an incoming call during the data slot of one of the epochs in which it listens, it can ring and enter operational mode to allow audio communication. Additionally, if a user turns on the handset to place a call, the handset also enters operational mode and transmits appropriate data to the base unit.

In operational mode, when a handset is off hook and being used, it is deactivated during most of the TDMA epoch, as in sleep mode, except that it turns on once for each epoch during the two data slots for the handset, and also turns on for two audio packets (an audio packet pair) for every field in which it is allocated an audio slot pair. For example, if handset 120_1 is operational, it will be on for data slots 251, 252 for each epoch, and also for the first two audio slots of the even row of each row pair (24 audio slots total). Thus, in one embodiment, when in operational mode, each handset is on for only two data packets and 24 audio packets of the entire TDMA epoch, a duty cycle of approximately 12% (26 slots/(9x12x2 slots)) (assuming 8 handsets are operational, so that a given handset has 2 audio slots every other field, instead of every field).

In both sleep and operational modes, therefore, the TDMA scheme and power saving protocol of the present invention provides for power to be efficiently used since each operating handset is off and thus not consuming much power, for most of the time (whether in sleep mode or off hook). This protocol is described in further detail below with reference to Fig. 3.

Referring now to Fig. 3, there is shown a state diagram of the power saving protocol 300 implemented by each handset 120_i of telephone system 100 of Fig. 1, in accordance with an embodiment of the present invention. Protocol 300 comprises 4 layers: inactive layer 310, initialization layer 320, standby link layer 330, and active link layer 340. Inactive layer 310 occurs when handset 120_i is out of contact with base unit 110. Initialization layer 320 occurs as the link is being established, i.e., when the handset is in the process of finding the RF channel, the carrier and timing offsets necessary to use the RF channel, and finally, the TDMA reference for the epoch. Standby layer 330 is used when the base and handset have obtained synchronization lock, and active link layer 340 exists when there is active audio communication. Thus, standby layer 330 corresponds to sleep mode and active link layer 340 corresponds to operational mode.

There are three reasons for being in inactive layer 310 (inactive state 311). First, if the handset or base is without power (power failure or battery changes in the handset); second, if the handset is turned off (unpowered); and third, the handset is out of range. Thus, the inactive layer 310 occurs when the handset has been out of synchronization for an extended period, such as battery changes, or staying out or range longer than local TDMA sync can hold. There are two ways to leave the inactive layer and begin initialization state 321 in initialization layer 320: first, the user can trigger the handset, initiating a search for the synchronization pulses transmitted by the base unit 110 for that handset during its respective data slot; second, the handset periodically self-initiates a search. However, such a

search is a power hungry operation, requiring continuous operation of the receiver.

Therefore, in a preferred embodiment, power usage is limited by reducing the frequency of self-initiated searches to once every several minutes. This allows an inactive handset to recover automatically in the event of base power failure. This technique thus provides a low cost alternative to base battery backup, and allows automatic recovery if the signal was lost because of straying out of range, without excessive battery drain. Thus, in the inactive layer, the handset may be configured to do nothing, until the user initiates establishment of a link, or a periodic timer stimulates the handset to search for the base's sync packet transmission. The base contiguously transmits synchronization packets at three different power levels when a link is in the inactive layer, as described previously.

Once the handset correlates to a base signal and leaves the inactive layer 310, the signal must be demodulated, and the handset must check to determine whether it belongs to the base it received a signal from, and it must also exchange time stamp information to synchronize the base and handset TDMA timers (states 321, 322 of initialization layer 320). Once the channel and TDMA timers are tuned, the link can reach standby link layer 330 (state 331). Time stamps are exchanged between the handset and base until the timing error is below a threshold value, at which point linked state 331 is achieved.

In standby/sleep mode, while the handset is "linked," the handset checks in only periodically with base 110 (i.e., every *n* seconds or *m* epochs) to receive a sync packet (data packet having synchronization data), at which point TDMA synchronize state 332 is

entered in order to synchronize the local clock. Time stamps are transmitted in the sync packet to allow the handset to keep the TDMA time in sync with the base. An "I'm alive" acknowledgment pulse may be transmitted back to base unit 110 when such a sync packet is successfully received. If the base fails to receive an acknowledge often enough, the link is considered broken by the base, and it will begin transmission at multiple power levels, as in the inactive layer.

Active communication (operational mode) occurs when the handset initiates a call (state 331 goes to state 342), or when the base requests that a handset answer a call (state 331 goes to state 341). Since the link is operating, these are initiated by the exchange of data packets. The data packet indicates that a call is coming in, and the base always monitors handset transmissions. During active communication, time stamps are not exchanged, but TDMA synchronization is maintained by examining the presence and absence of communication packets. The point where sequential correlation peaks have been observed until when they disappear provides and edge that gives a robust indication of the phase of the TDMA timer. Since packets occur consistently during active communication, TDMA phase is maintained by examining the edges of packets.

TDMA frequency lock is important only for long periods without communication, such as what occurs in the standby link layer 330 (sleep mode), since the frequency reference is typically provided by a very accurate quartz crystal oscillator in both the handset and base. Upon completion of a call, time stamps will be exchanged in standby link layer 330 to occasionally adjust the local clock so as to maintain TDMA reference frequency lock. The unadjusted TDMA time base is still quite accurate, being derived from a quartz oscillator, and will

time out TDMA slots over an epoch with plenty of margin. By adjusting the time base with a time stamp based frequency locked loop, the time base will be accurate over several TDMA epochs, allowing the handset to poll for data at a minimal rate.

One advantage of the protocol of the present invention is that, once synchronized, the handset need only poll the specific data time slot where ring and time stamp data would be transmitted. The handset does not even need to poll every epoch, as the protocol will allow the user many epochs to respond to an incoming call, and many epochs can pass before the base will consider the handset out of sync. The sync packets contain time stamps to keep the TDMA links frequency locked, and the edges of the data packets keep the TDMA links phase locked. In the TDMA system of the present invention, assuming a 1 second poll rate (about 20 TDMA data epochs) for incoming calls, this amounts to a handset receiver 122 on duty cycle of about 0.02% (200 μs/packet). Acknowledging would run the handset transmitter 121 at the same rate.

One skilled in the art will recognize that the wireless system described above according to the principles of the invention may be a cellular system where base unit 110 represents a base station serving one of the cells in a cellular telephone network.

It will be understood that various changes in the details, materials, and arrangements of the parts which have been described and illustrated above in order to explain the nature of this invention may be made by those skilled in the art without departing from the principle and scope of the invention as recited in the following claims.

CLAIMS

1. A wireless telephone system, comprising:

(a) a base unit having a base transceiver; and

(b) one or more wireless handsets, each handset comprising a handset transceiver for establishing a time-division multiple access (TDMA) link over a shared RF channel with the base unit via the base transceiver in accordance with a TDMA epoch allocating packet time slots to each handset, wherein each handset is adapted to power on its transceiver during its respective packet time slots for synchronizing with the base unit, the handset being adapted to power off its transceiver otherwise during the epoch.

2. The system of claim 1, wherein each handset is further adapted to power on its transceiver during its respective data and audio packet time slots as necessary to detect incoming call data transmitted with a data packet or to transmit and receive audio information over the TDMA link.

3. The system of claim 1, wherein:

the epoch has a plurality of transmit and receive data row pairs, one such row pair for each handset; and

each handset, when in operational mode, receives and transmits data packets via receive and transmit data packet slots only once during each epoch, during the transmit and receive data row pair for each said operational handset, and receives and transmits audio packets during allocated audio time slots of the epoch for the handset.

4. The system of claim 1, wherein:

each handset may be in an operational mode when the handset is off hook or in a sleep mode when the handset is on hook;

each handset comprises a local clock and watchdog timer that remain operational even when the handset transceiver is powered off;

when the handset is in sleep mode, the handset powers on its transceiver, in response to the watchdog timer, during its respective receive data packet time slot of the epoch as necessary to synchronize with the base unit by synchronizing on synchronization information contained in the received data packet.

5. The system of claim 4, wherein:

each handset is always in a state within one of the following layers: an inactive layer, an initialization layer, a standby link layer, and an active link layer;

the inactive layer occurs when the handset is out of contact with the base unit;

the initialization layer occurs as a TDMA link is being established between the handset and the base unit;

the standby link layer occurs when the base unit and handset have obtained synchronization lock, and comprises the sleep mode; and

the active link layer occurs when there is active audio communication between the handset and the base unit and comprises the operational mode.

6. The system of claim 4, wherein when the handset is in sleep mode, the handset powers on its transceiver during its respective receive data time slot of each epoch to receive a data packet containing synchronization information.

7. The system of claim 6, wherein after receiving the data packet during the receive data time slot, the handset transmits a data packet to the base unit during the transmit data time slot for the handset to notify the base unit that the handset is still synchronized with the base unit.

8. The system of claim 7, wherein, if the base unit does not receive the data packet from a handset to notify the base unit that the handset is still synchronized with the base unit, after the base unit has transmitted a data packet to the handset containing synchronization information, then the base unit attempts to restore synchronization with the handset by transmitting subsequent data packets to the handset with synchronization information during the transmit data time slot for the handset at increasing power levels.

9. The system of claim 4, wherein when the handset is in sleep mode, the handset powers on its transceiver during its respective receive data time slot of every Nth epoch, wherein the handset is able to maintain synchronization with the base unit over a time period lasting at least N epochs without receiving a data packet from the base unit.

10. The system of claim 4, wherein when the handset is in sleep mode, the handset powers on its transceiver, in response to the watchdog timer, during its respective receive data packet time slot of the epoch as necessary to synchronize with the base unit by synchronizing on synchronization information contained in the received data packet.

11. In a wireless telephone system having a base unit and one or more wireless handsets, the base unit having a base transceiver and each handset having a handset transceiver, a method comprising the steps of:

(a) establishing, with the handset transceiver for each handset, a time-division multiple access (TDMA) link over a shared RF channel between the handset and the base unit via the base transceiver in accordance with a TDMA epoch allocating exclusive data and audio packet time slots to each handset;

(b) for each handset, powering on its transceiver during its respective data and audio packet time slots as necessary to synchronize with the base unit using synchronization data transmitted with a data packet; and

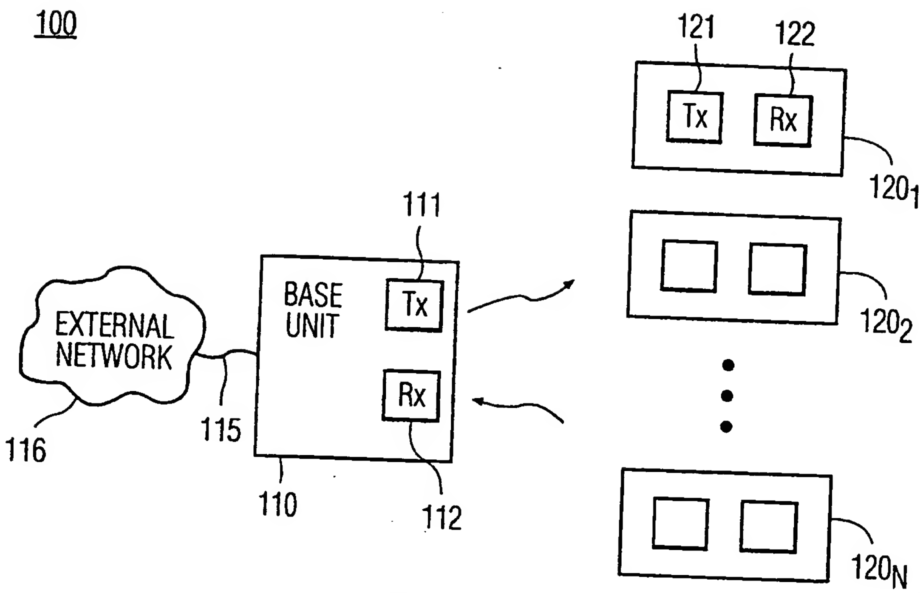
(c) for each handset, powering off its transceiver otherwise during the epoch to minimize handset power use.

12. A wireless handset for use with a wireless telephone system having a base unit and a plurality of wireless handsets including the wireless handset, the base unit having a base transceiver and each handset having a handset transceiver, the wireless handset comprising:

(a) a handset transceiver for establishing a time-division multiple access (TDMA) link over a shared RF channel with the base unit via the base transceiver in accordance with a TDMA epoch allocating exclusive data and audio packet time slots to each handset of the plurality of handsets;

(b) means for powering on the handset transceiver during its respective data and audio packet time slots as necessary to synchronize with the base unit using synchronization data transmitted with a data packet; and

(c) means for powering off the handset transceiver otherwise during the epoch to minimize handset power use.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121
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Tx
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120₁
111
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Tx
EXTERNAL NETWORK
Rx
120₂
116
115
110
112
120N

FIG. 1

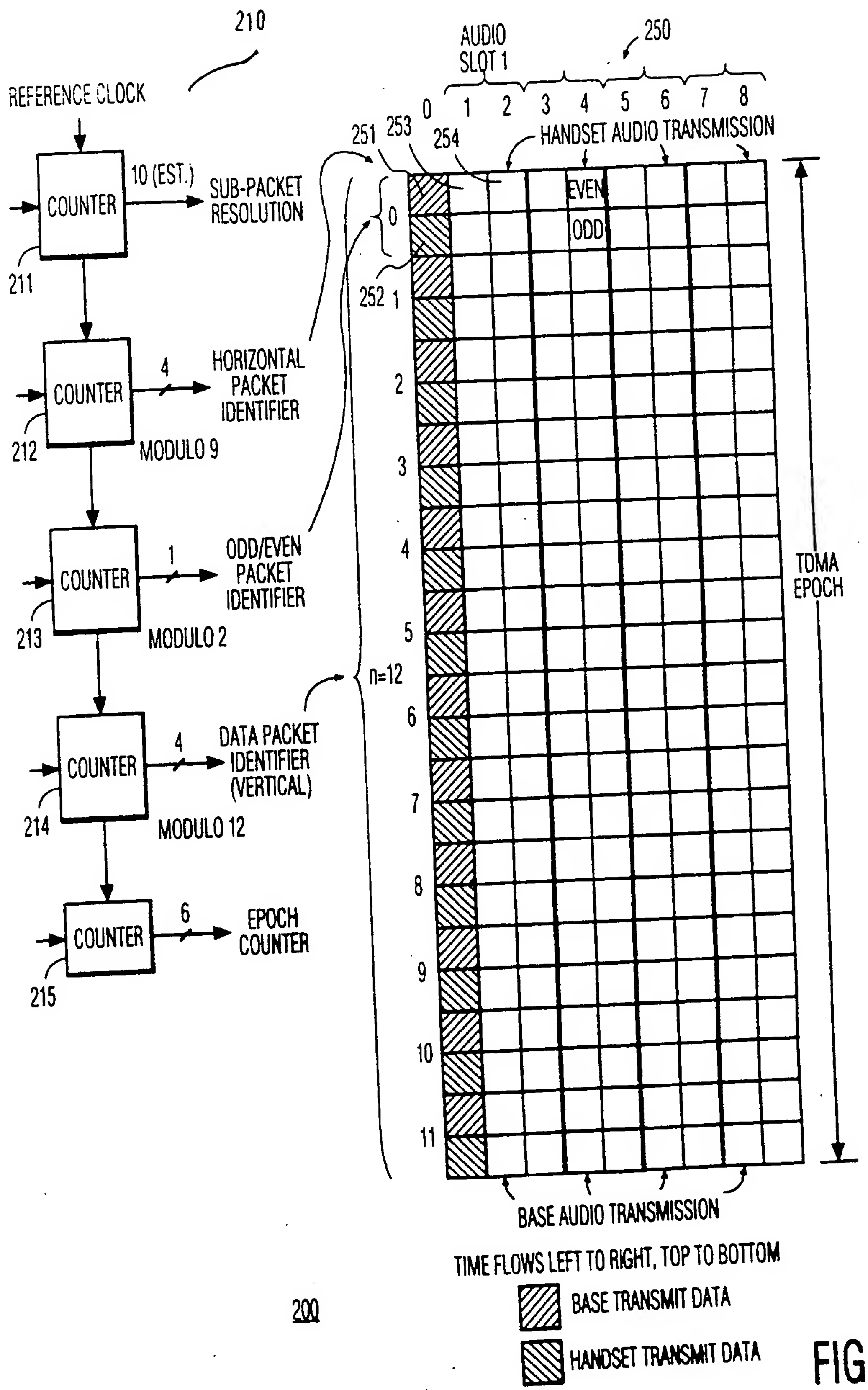
210
REFERENCE CLOCK
COUNTER
10 (EST.)
SUB-PACKET RESOLUTION
211
COUNTER
4
HORIZONTAL PACKET IDENTIFIER
212
MODULO 9
COUNTER
1
ODD/EVEN PACKET IDENTIFIER
213
MODULO 2
COUNTER
4
DATA PACKET IDENTIFIER (VERTICAL)
214
MODULO 12
COUNTER
6
EPOCH COUNTER
215
AUDIO SLOT 1
250
0 1 2 3 4 5 6 7 8
251 253 254
HANDSET AUDIO TRANSMISSION
EVEN
ODD
252
0 1 2 3 4 5 6 7 8 9 10 11
n=12
TDMA EPOCH
BASE AUDIO TRANSMISSION
TIME FLOWS LEFT TO RIGHT, TOP TO BOTTOM
BASE TRANSMIT DATA
HANDSET TRANSMIT DATA
200

FIG. 2

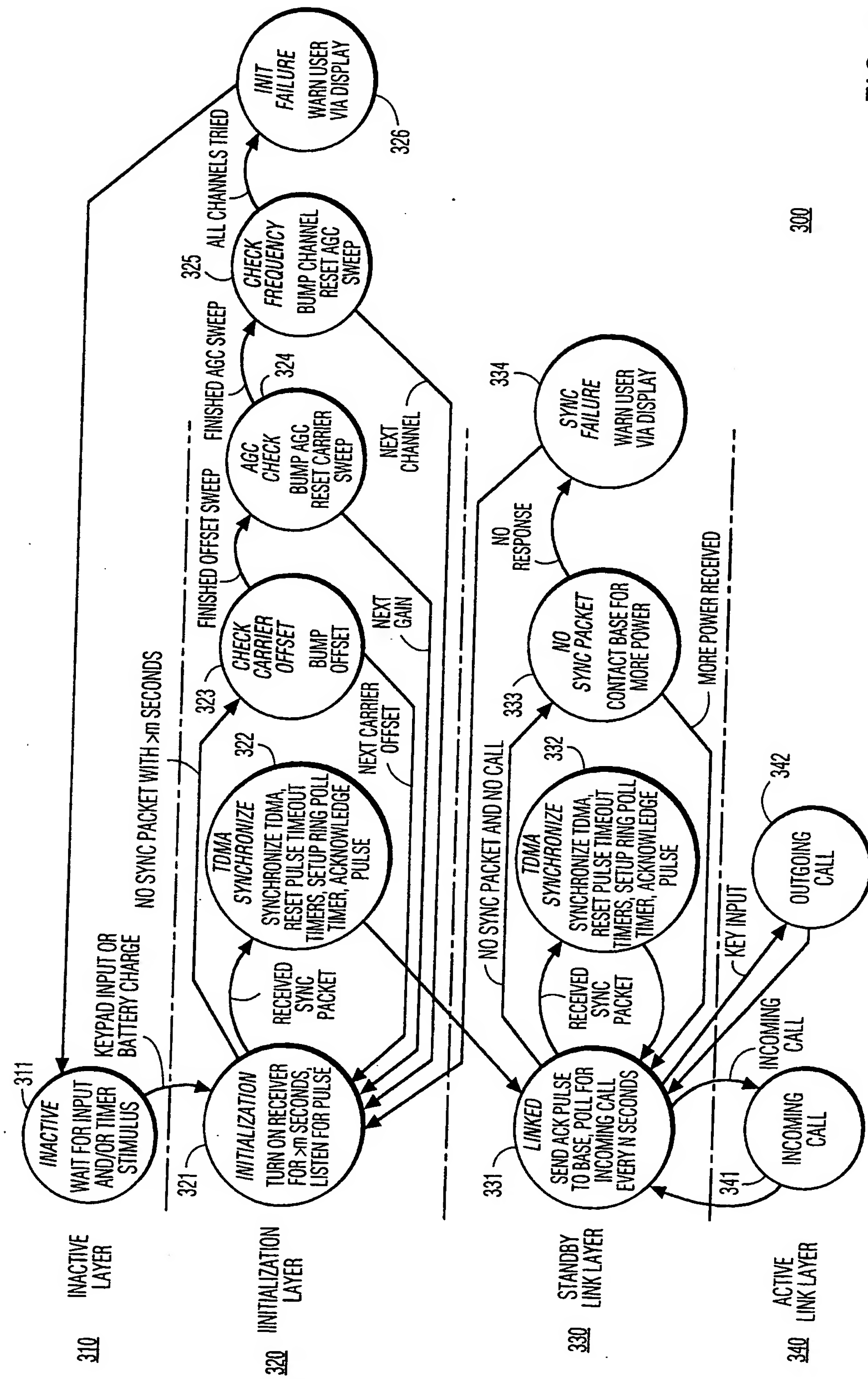
310 INACTIVE LAYER
320 IINITIALIZATION LAYER
330 STANDBY LINK LAYER
340 ACTIVE LINK LAYER
311
INACTIVE
WAIT FOR INPUT AND/OR TIMER STIMULUS
KEYPAD INPUT OR BATTERY CHARGE
321
INITIALIZATION
TURN ON RECEIVER FOR >m SECONDS, LISTEN FOR PULSE
RECEIVED SYNC PACKET
322
TDMA SYNCHRONIZE
SYNCHRONIZE TDMA, RESET PULSE TIMEOUT TIMERS, SETUP RING POLL TIMER, ACKNOWLEDGE PULSE
NO SYNC PACKET WITH >m SECONDS
323
CHECK CARRIER OFFSET
BUMP OFFSET
NEXT CARRIER OFFSET
FINISHED OFFSET SWEEP
NEXT GAIN
324
AGC CHECK
BUMP AGC RESET CARRIER SWEEP
FINISHED AGC SWEEP
NEXT CHANNEL
325
CHECK FREQUENCY
BUMP CHANNEL RESET AGC SWEEP
ALL CHANNELS TRIED
326
INIT FAILURE
WARN USER VIA DISPLAY
331
LINKED
SEND ACK PULSE TO BASE, POLL FOR INCOMING CALL EVERY N SECONDS
RECEIVED SYNC PACKET
332
TDMA SYNCHRONIZE
SYNCHRONIZE TDMA, RESET PULSE TIMEOUT TIMERS, SETUP RING POLL TIMER, ACKNOWLEDGE PULSE
NO SYNC PACKET AND NO CALL
333
NO SYNC PACKET
CONTACT BASE FOR MORE POWER
MORE POWER RECEIVED
NO RESPONSE
334
SYNC FAILURE
WARN USER VIA DISPLAY
341
INCOMING CALL
INCOMING CALL
KEY INPUT
342
OUTGOING CALL
300

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/18061

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B1/16 H04M1/72 H04Q7/32 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B H04M H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 964 121 A (MOORE MORRIS A) 16 October 1990 see column 2, line 43 - line 64 see column 4, line 45 - line 60 see column 7, line 32 - line 57 see column 8, line 9 - line 45 see column 10, line 16 - line 29 see figures 5,6 ---	1,2,4-6, 9-12
X	US 5 150 361 A (KLUESING ALVIN D ET AL) 22 September 1992 see column 2, line 3 - line 22 see column 4, line 39 - column 5, line 14 see column 5, line 50 - line 64 see column 6, line 5 - line 38 see column 6, line 68 - column 7, line 5 see figures 3-6 ---	1,3,4,6, 11,12

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 December 1998	18/12/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Cochet, B

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International Application No
PCT/US 98/18061

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 726 687 A (NOKIA MOBILE PHONES LTD) 14 August 1996 see column 3, line 23 - line 38 see column 4, line 45 - column 5, line 53 see column 7, line 30 - line 52 see column 8, line 36 - line 53 see figures 2-5,7	1,4,6,9, 10
A	US 4 398 192 A (MOORE MORRIS A ET AL) 9 August 1983 see column 4, line 56 - column 5, line 66; figure 6	9
A	EP 0 661 836 A (ALCATEL STANDARD ELECTRICA) 5 July 1995 see column 2, line 25 - line 36; figure 2	1

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int .ional Application No
PCT/US 98/18061

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 4964121	A	16-10-1990	CA	2065331 A,C	01-03-1991
			EP	0489838 A	17-06-1992
			JP	5500293 T	21-01-1993
			KR	9513309 B	02-11-1995
			WO	9103884 A	21-03-1991
US 5150361	A	22-09-1992	CA	2002603 A,C	23-07-1990
EP 0726687	A	14-08-1996	GB	2297884 A	14-08-1996
			JP	8251656 A	27-09-1996
			US	5737323 A	07-04-1998
US 4398192	A	09-08-1983	NONE		
EP 0661836	A	05-07-1995	ES	2078179 A	01-12-1995
			AU	690933 B	07-05-1998
			AU	8029894 A	13-07-1995
			CA	2136127 A	01-07-1995
			FI	945675 A	01-07-1995
			JP	7264673 A	13-10-1995
			NZ	270095 A	20-12-1996
			US	5553077 A	03-09-1996